Study of the decay $B^+ \to K^+\pi^0$ at LHCb

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On behalf of the LHCb collaboration

Motivation

Analysis of $B^0 \to K^+\pi^-$ established direct CP violation in B mesons

$B \to K\pi$ system is a cornerstone of B meson CP violation studies

Table 1: $\mathcal{A}^{CP}$ measurements for the $B \to K\pi$ decay modes.

	BaBar	Belle
$B^0 \to K^0\pi^0$	$+0.13 \pm 0.13 \pm 0.03$ [1]	$+0.14 \pm 0.13 \pm 0.06$ [2]
$B^+ \to K^0\pi^+$	$-0.029 \pm 0.039 \pm 0.010$ [3]	$-0.011 \pm 0.021 \pm 0.006$ [4]
$B^0 \to K^+\pi^-$	$-0.107 \pm 0.016^{+0.006}_{-0.004}$ [5]	$-0.069 \pm 0.014 \pm 0.007$ [4]
$B^+ \to K^+\pi^0$	$+0.030 \pm 0.039 \pm 0.010$ [6]	$+0.043 \pm 0.024 \pm 0.002$ [4]

Measurements of the entire system have revealed significant deviations from the expected patterns of CP violation

[1] PRD D79 (2009) 052003
[2] PRD D81 (2010) 011101
[3] PRL 97 (2006) 171805
[4] PRD D87 (2013) 031103
[5] PRD D87 (2013) 052009
[6] PRD D79 (2007) 091102
[7] PRL 108 (2012) 201601

Table 2: $\mathcal{A}^{CP}$ measurement and world averages for the $B \to K^+\pi$ decay modes.

	$B^0 \to K^+\pi^-$	$B^+ \to K^+\pi^0$
LHCb [7]	$-0.088 \pm 0.011 \pm 0.008$	n/a
World average	-0.082 ± 0.006	0.040 ± 0.021

- Direct CP violation in $B^+ \to K^+\pi^0$ not established, but is naively expected to be the same as in $B^0 \to K^+\pi^-$
- This is the $K\pi$ puzzle, discovered at the B factories
  - $\Delta A_{CP}(K\pi) \equiv A_{CP}(B^+ \to K^+\pi^0) - A_{CP}(B^0 \to K^+\pi^-) \neq 0$
- Evidence for $A_{CP}(K^+\pi^0)$ is ambiguous (consistent with zero at 2σ)

Room for improvement!

$B^+ \to K^+\pi^0$ at LHCb

At LHCb, this study also serves as a prototype for analyses with similar topologies, such as $B^0 \to K^0\pi^0$, $\Lambda_b \to \Lambda\gamma$, and $B^0 \to K^0\pi^0\gamma$

Important modes to study, yet very challenging at LHCb

- No secondary vertex, photons in final state

Analysis of $B^+ \to K^+\pi^0$ is a critical first step, and a proof-of-concept

Challenges

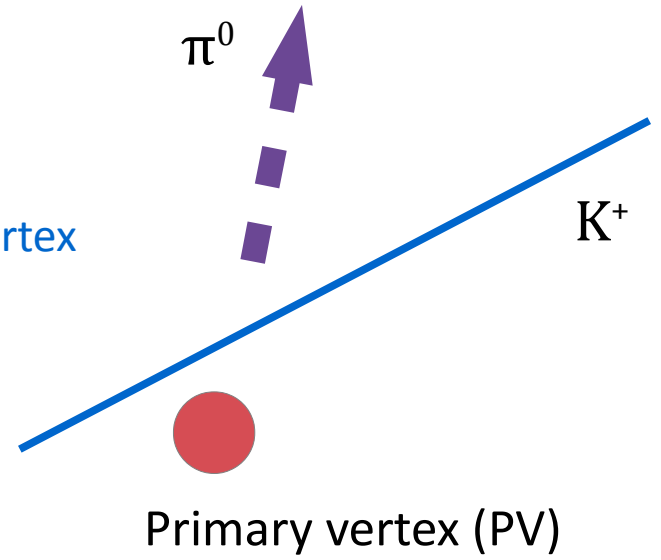
Little to reconstruct

- Only a single charged track
- No secondary vertex

Inclusive triggering at LHCb based on detection of secondary vertex

- Signal decays will not fire the high-level software trigger

Very large combinatorial background expected



$B^+ \to K^+\pi^0$ at LHCb

Strategy

Reconstruct high-E_T π^0's

Apply track isolation and vertex isolation/rejection

Find a way to exploit the significant displacement of the B^+ from the PV

Reject a huge amount of background as efficiently as possible using a multivariate classifier

- Possible partially reconstructed backgrounds: $B \to K^*\pi^0$, $B \to K^+\rho$, etc.

This analysis studies the full $3.0\ fb^{-1}$ data set collected in Run I

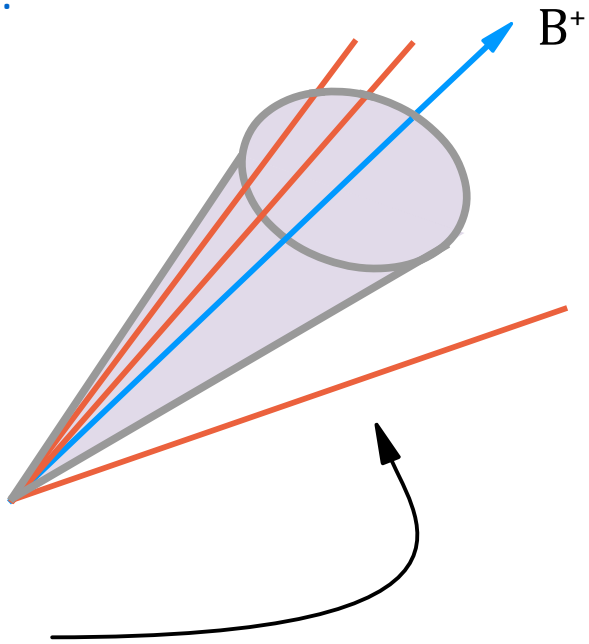
Isolation

Track isolation

A number of variables are calculated from non-signal tracks within a "cone" of η and φ about the signal candidate. We use:

1. Multiplicity of tracks in the cone
2. PT asymmetry of tracks in the cone:

$$A_{PT} \equiv \frac{PT^{B} - PT^{cone}}{PT^{B} + PT^{cone}}$$



Vertex rejection

Count the multiplicity of other tracks in the event which make a good vertex with the K^+

- "Good" means χ^2 of a vertex is < 9

MT-DOCA

A new variable invented for this analysis

Mother-Trajectory Distance-of-Closest-Approach

1) Make a trajectory in the direction of the B^+ momentum from the PV of the K^+
2) Calculate the DOCA that the track makes with this trajectory

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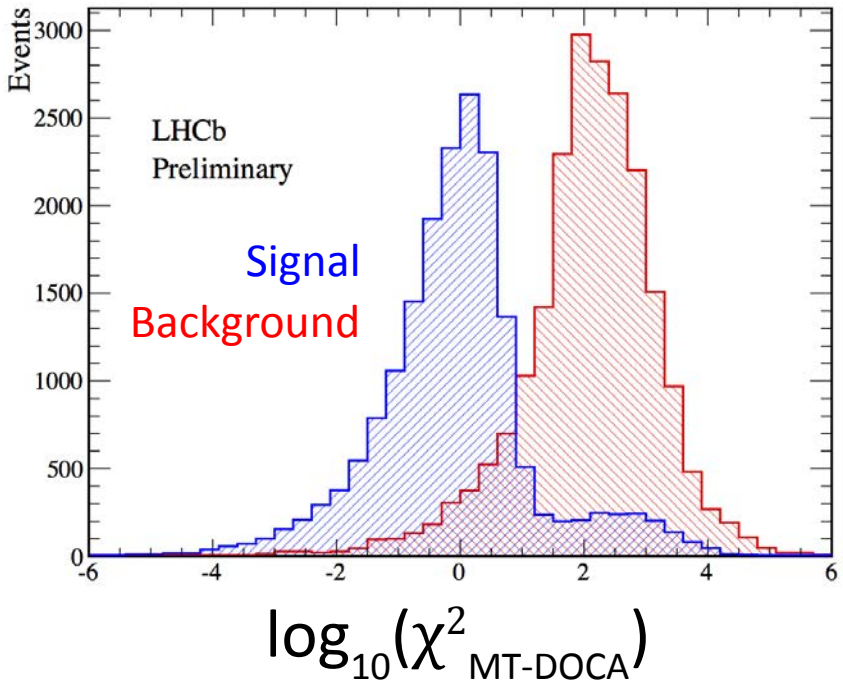
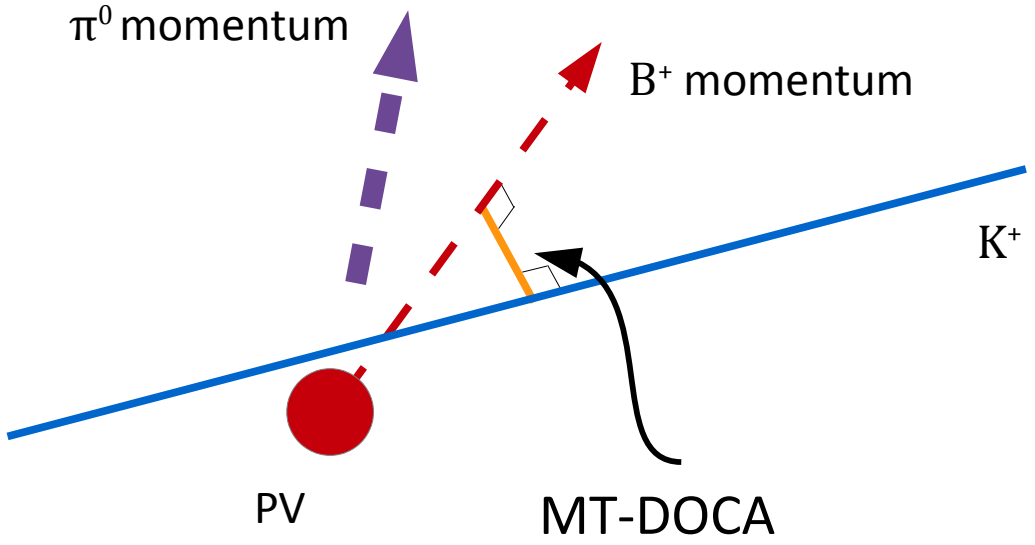




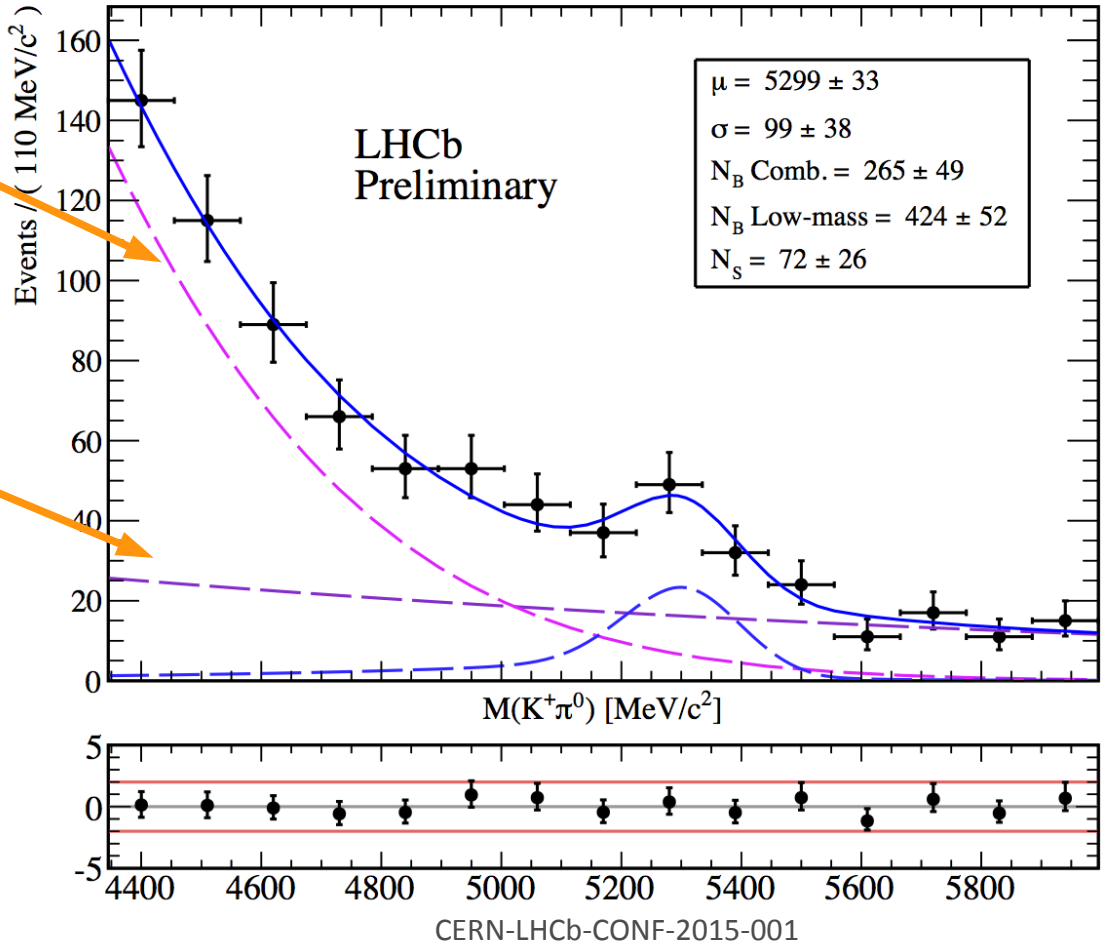
Results

Low-mass background modeled with the tail of a Gaussian, parameters floating

Combinatorial modeled with an exponential, shape fixed from upper sideband fit

Signal mean and width floating

Contributions from $B \to K^*\pi^0$, $B \to K^+\rho$, $B \to K^*\gamma$ all found to be negligible



72 ± 26 signal events at 3.7σ significance:
the first observation of this mode at a hadron collider

Plans for Run II

Encouraged by the outcome of this analysis, a dedicated software trigger is being developed for use in Run II

Conservatively, we expect 700 – 1100 events per fb^{-1} in Run II, with an error of about 100 events, based on a factor of 3 – 5 times improvement in trigger efficiency

Cf. BaBar: 1364 ± 57; From 383 X 10^6 $B\bar{B}$ events PRD D79 (2007) 091102

Belle: 3731 ± 92 From 772 X 10^6 $B\bar{B}$ events PRD D87 (2013) 031103

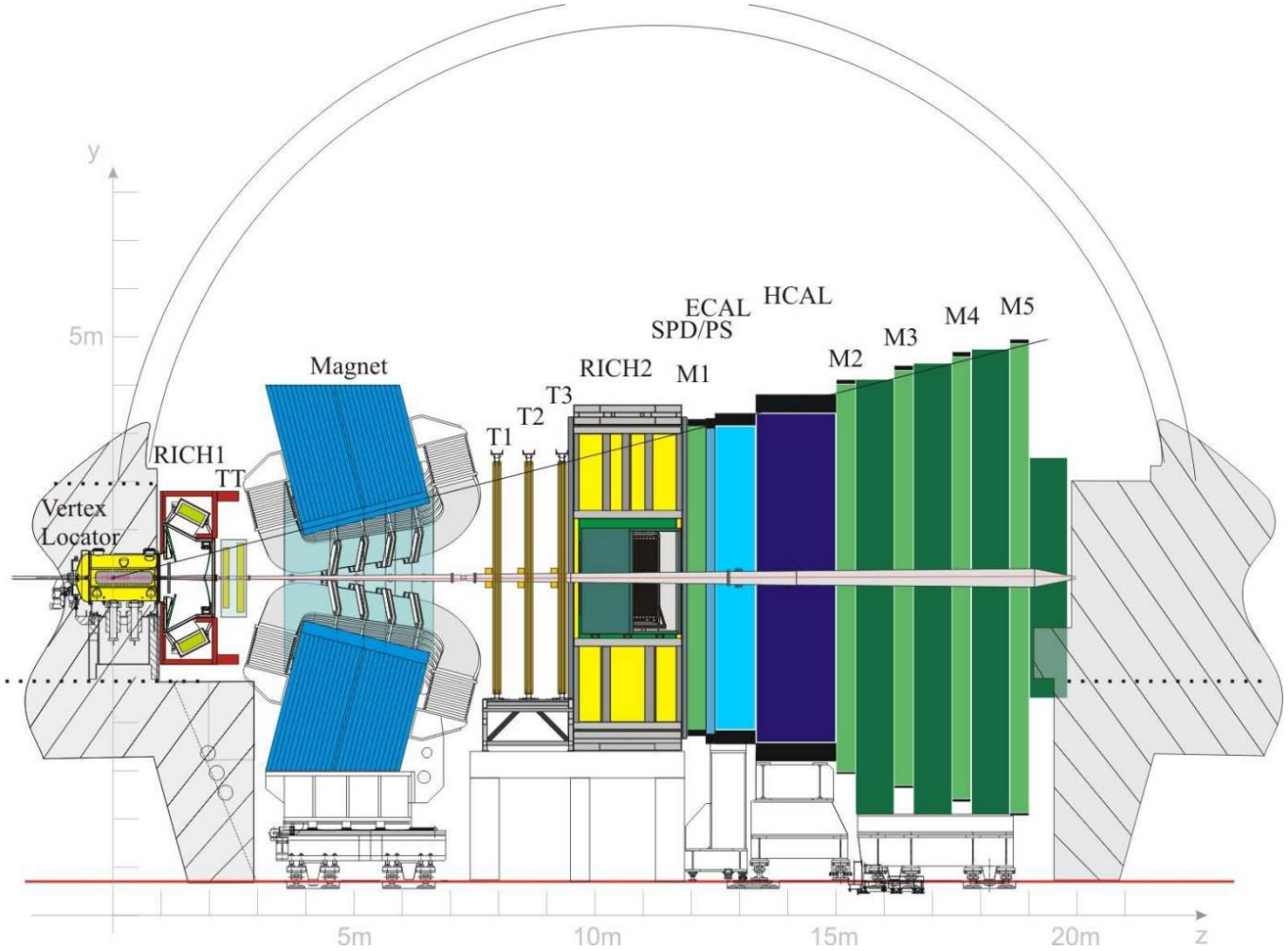
Conclusion

An analysis of $B^+ \to K^+\pi^0$ is performed using the Run I LHCb data set

This is the first observation of this mode at a hadron collider, demonstrating the potential of LHCb to make measurements of modes with this kind of topology

We expect to contribute competitive measurements

Backup



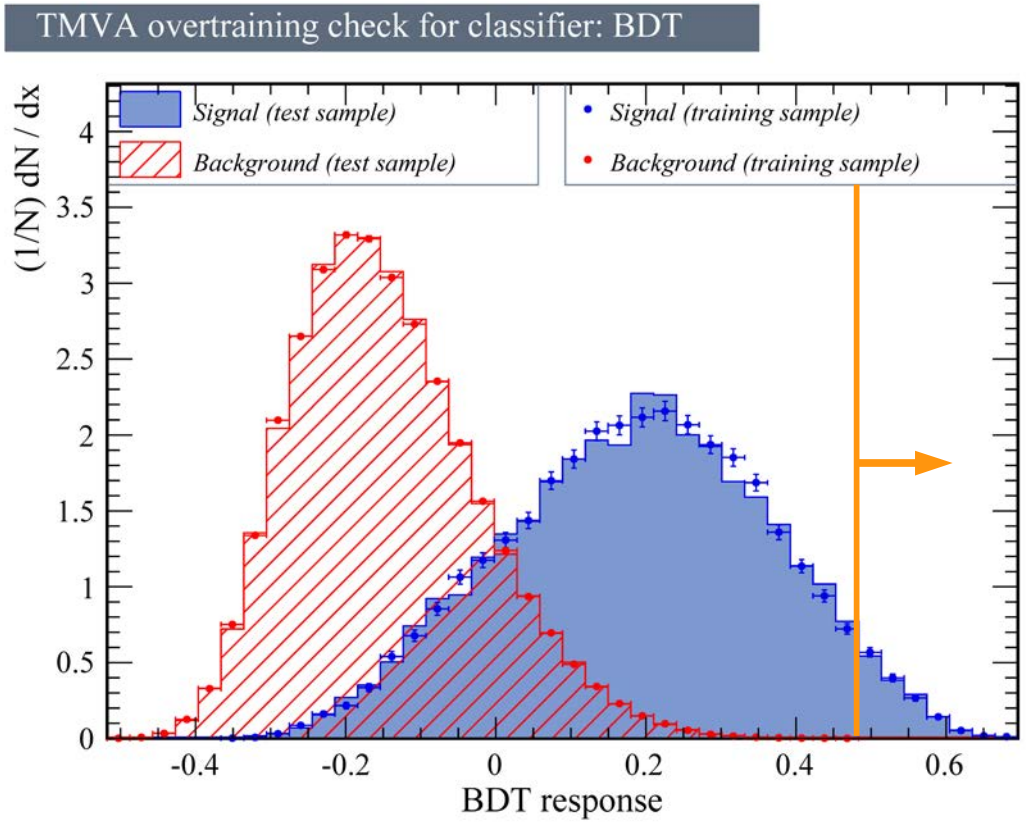
Momentum resolution: $\Delta p / p = 0.5\ \%$ at low momentum to $1.0\ \%$ at $200\ \mathrm{GeV}/c$

Impact parameter resolution: $(15+29/p_T)\ \mu m$

ECAL energy resolution: $1\ \% + 10\ \% / \sqrt{(E[\mathrm{GeV}])}$

MVA classifier

- BDT found to perform the best
- Variables used:
  - Isolation, MT-DOCA, kinematics, K^+ impact parameter with PV



- Using optimal point of $S/\sqrt{S+B}$ figure-of-merit
- Low signal efficiency – enormous background to reject